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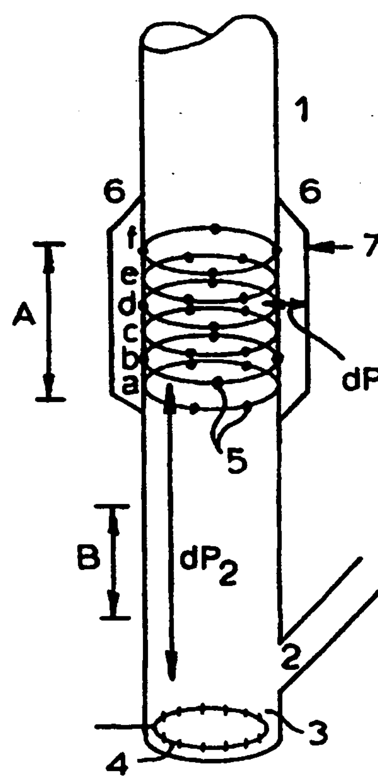
(57) Abstract

Process and apparatus for mixing a first fluid into a stream of second fluid wherein fluids undergo rapid successive momentum exchange rendering a mixed fluids stream with momentum substantially in axial direction and in which first fluid is radially distributed.



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PROCESS AND APPARATUS FOR MIXING FLUIDS

The present invention relates to a process and an apparatus for mixing fluids for transport as a mixed fluids stream, particularly for mixing reactive fluids for reaction during transport in plug flow.

It is desirable in certain instances to employ such a process or apparatus wherein mixing takes place in situ in the combined stream, dispensing with the need to premix fluids by means of for example stirring. Benefits include reduced hardware costs, reduced contact time (of particular advantage when mixing streams for rapid reaction), reduced attrition of fluidised solids and improved mixing of segregable fluids.

Plug flow may be defined as stream-flow with zero backmixing, i.e. with uniform velocity component in fluid stream direction. In practice, even when initially brought in plug flow, frictional deceleration at the walls of a fluid conduit through which a fluid stream is transported typically induces peripheral backmixing and flow segregation. Flow segregation is particularly prone to occur with fluid, particularly fluidised solids in fluid vertically upward flow, as a result of gravitational force on solid components, which solids as a result tend to segregate towards the lower velocity fluid flow at the walls of the conduit. This problem has been observed to magnify with increase in conduit diameter.

This problem is of particular relevance to mixing in a riser type fluid catalytic cracking (FCC) process in which liquid hydrocarbonaceous feed in atomised suspension in an atomising gas and a stream of hot fluidised catalyst particles at elevated temperature,

typically of 500 to 700C are introduced to the liftpot base portion of a riser reactor and transported upwardly for a short contact time, typically less than 10 seconds during which contact of feed and catalyst causes both feed evaporation whereby contact with catalyst is enhanced, and catalytic cracking to hydrocarbonaceous products of lower molecular weights which are separated from the catalyst. It is desirable to transport the feedstock and catalyst in plug flow for improved contacting and improved product yields. Break down in plug flow leads to non-selective thermal cracking of a portion of feed which fails to directly contact catalyst, and to high severity overcracking of a portion of feed which is contacted with high concentration of catalyst. Coking by thermal cracking of feed on contact with the opening of a feed inlet or the reactor wall, can impair feed injection and further disturb riser flow.

The problem is also of particular relevance to mixing in a riser type process for flue gas treating in which fluidised sulphur oxide adsorbent particles and sulphur oxide(s) containing flue gas derived typically from an FCC catalyst regenerator, at elevated temperature, typically 750 to 850C are introduced to the base liftpot portion of a riser and transported upwardly in lean phase flow, for short contact times during which rapid adsorption of sulphur oxides takes place. Segregation in flue gas treating reactors leads to poor levels of adsorption rendering treated gases with levels of noxious gases such as sulphur oxides above environmentally acceptable limits for disposal as waste gas.

Known means aimed at achieving and sustaining plug flow are of limited effect. Riser conduits of reduced diameter must be of extended height whereby riser residence time is increased which may be disadvantageous to performance. FCC operation with greater riser

velocities achieved by greater lift force on catalyst or with vertically upward injection of feed from within the catalyst flow path introduces further problems of attrition of fluidised catalyst particles and of mechanical stress. In US patent specification 5,139,748 is disclosed an FCC process employing high velocity perpendicular injection of feed into catalyst flow for improved radial penetration whereby problems of erosion or coking of the liftpot wall opposite to the feed inlet are addressed by provision of an axial strike surface opposite feed inlets. This may introduce a new problem by wetting of the strike surface with resultant thermal cracking and coking at the strike surface. Diversion of the fluidised catalyst stream around the strike surface, aggravated by coke build up, may severely disrupt the mixed phase flow and cause segregation.

We have now found that plug flow is substantially achieved with a process and apparatus for mixing first and second fluids providing a high rate of momentum exchange and intensive radial mixing of the respective fluids. It has moreover been found that plug flow may be maintained for appreciable distances along the combined flow path by control of momentum exchange to provide a peripheral annulus of fluid of low frictional value. It is of particular advantage that the process and apparatus of the present invention are essentially scale independent.

Accordingly the present invention relates to a process for mixing a first fluid into a substantially vertically upward stream of second fluid having momentum substantially in stream axial direction, wherein both first and second fluids comprise a reactive component which components when brought into contact undergo rapid reaction within a contact time of less than 10 seconds, and wherein first fluid is heterogeneous and comprises

the reactive component as the more dense of the heterogeneous components and a substantially inert component as the less dense of the heterogeneous components, which process comprises introduction into the second fluid stream of first fluid having a momentum component perpendicular to the momentum in stream axial direction of second fluid, characterised in that the first fluid is introduced substantially circumferentially about a length of the second fluid stream such that the second fluid stream is subjected to successive momentum exchange with the circumferential length introduced first fluid rendering a substantially vertically upward mixed fluids stream in which first fluid is radially distributed, with momentum substantially in stream axial direction.

Reference herein to "reactive" or "substantially inert" fluid components are to any fluid components which in combination transform, or not, in any desired manner under the conditions of the process of the invention. Suitably "reactive" or "substantially inert" fluid components may include a catalyst, adsorbent or active agent and the substrate which it is capable, or not, of catalytically transforming, of adsorbing or converting.

Reference herein to a momentum component is to a constituent portion of the momentum, respectively co-parallel, radial or tangential with respect to second fluid stream axial direction, calculated by resolution of the momentum vector.

Reference herein to successive momentum exchange of second fluid with first fluid is to that exchange which takes place along its flow path of any given second or first fluid entity on contact with a plurality of first or second fluid entities respectively, wherein an entity may be defined as a discrete unit of fluid, such as a molecule, or gaseous cluster, droplet or particle

thereof.

Reference herein to a first or second fluid component is to a distinct phase or a distinct chemical type comprised in a multiple phase or multiple chemical type first or second fluid. Preferably fluids comprising a liquid or fluidised solid comprise in addition a dispersive, atomising or aerating gaseous component. Preferably first fluid is heterogeneous comprising fluidised solid particles or atomised liquid as the more dense reactive component and gaseous fluid as the less dense substantially inert component. Preferably second fluid comprises fluidised solid particles or gaseous fluid as the reactive component.

By the process of the present invention, successive momentum exchange provides enhanced contact of first and second fluids. Momentum density ratios of respective fluids may be selected such that entities of highest density first fluid component(s) undergo full momentum exchange and change in momentum direction only on penetration to the core of the second fluid stream and entities of highest density second fluid component(s) fully absorb momentum perpendicular to the stream axis and are constrained from the peripheral annulus thereabout with no net deviation of momentum direction. By this means lowest density components of the mixed fluid stream absorb surface stream effects with substantially no deceleration thereby serving as a "lubricant" for highest density components which are constrained from the periphery of the mixed stream for a substantial downstream distance thereby preserving plug flow.

Preferably first and second "reactive" fluid components react to form a lower density inert low friction product or component. Without being bound to the following theory, a low density product of reaction of

components of first and second fluids is thought to displace towards the peripheral annular stream portion, whereby the plug flow regime is further preserved and the product is removed from the mixed stream axial reaction zone, preventing further undesired reaction thereof.

It is stated that the process of the invention is substantially scale independent. It is found that by selection of an appropriate circumferential introduction length and rate, as hereinafter defined, the process may be operated for mixing of streams of any diameter or volume. Suitably the process may be operated for mixing of first fluid into a second fluid stream of diameter of 0.05m or less to more than 3.0m. Typical mixed stream diameters required in the presently envisaged applications lie in the range of 0.5 to 2.5m, typically about 1.0 to 2.0m.

The first fluid is suitably introduced according to the invention, at a distance downstream of the source of second fluid at which second fluid has achieved stable and uniform vertically upward flow, which distance is dependent both on the diameter and flow rate of the second fluid stream and on the nature of second fluid.

In a preferred aspect of the invention there is provided a process as hereinbefore defined wherein the substantially inert, less dense component of first fluid or other known transfer or lift gas, is introduced in a first upstream circumferential introduction length or at the upstream portion of the circumferential introduction length, and the first fluid is introduced as hereinbefore defined at a second downstream circumferential introduction length, or at the downstream portion of the circumferential introduction length. By this means it is advantageously found that the second fluid stream achieves stable and normal vertically upward flow in a shorter distance from the source thereof, whereby the

first fluid may be introduced at a shorter distance from the second fluid stream source. This is of particular advantage with application in an FCC process, whereby the height of the riser reactor may be reduced or, whereby a greater riser reaction volume may be achieved for the same riser height.

The process of the invention may be repeated at discrete stages along the length of the second stream, whereby first fluid of the same or different types may be introduced in staged manner or whereby highly reactive first fluid may be introduced at low space velocity.

Momentum of first and second fluids may be suitably controlled by regulation of their flow rates, respectively at the circumference of the second fluid stream and at the upstream end of the circumferential introduction length. Fluid flow rates may be regulated by known means such as by means of valves, of pressure drop or introduction of transfer fluids as a component of the respective fluid. A transfer gas may be the same as or different to, and is preferably the same as a fluidising or atomising gas introduced in admixture with fluidised solids or viscous liquids, and is suitably selected from an inert light gas or vapour, such as steam and light hydrocarbonaceous gases.

Typically a transfer gas is present in an amount of 0.1-50 wt%, preferably 1-15 wt% in viscous liquid, such as hydrocarbonaceous feed, for atomising and momentum control purposes, for example in FCC application as first fluid.

Typically a transfer gas is present in an amount of 0.01-5 wt%, preferably 0.05-1 wt% in fluidised solids, such as FCC catalyst particles or sulphur oxides adsorption particles, for fluidising and momentum control purposes as second or first fluid respectively. In a particular advantage of the process of the present

invention circumferentially introduced first fluid has momentum components selected for mutual coincidence, and for maximum penetration of first fluid equal to 0.5 times the diameter of the second fluid stream whereby radial uniform distribution is optimised.

Suitably first fluid is introduced discretely about a length of the second fluid stream via discrete circumferential introduction locations along the flow path of the second fluid stream, for example via circumferential introduction locations comprising a plurality of planes perpendicular to and along a length of the second fluid stream.

Suitably circumferential introduction is about a length of the second fluid stream of sufficient extent to achieve successive momentum exchange of second fluid, and is preferably about a length of the second fluid stream at least equal to the sum of n times the width, in second fluid downstream direction, of a circumferential introduction location and of (n-1) times the radius of the second fluid stream, wherein n = the number of circumferential introduction locations.

Suitably substantially circumferential introduction of first fluid about the second fluid stream is achieved discretely, i.e via introduction locations distributed about the second fluid stream circumference. Preferably introduction locations in a first plane are non aligned with respect to those in at least one other plane. More preferably introduction locations in a first plane are non aligned with respect to those in an adjacent plane. Most preferably introduction locations in any two adjacent planes have a triangular pitch which may be equilateral or otherwise. Rapidity of momentum transfer is increased by increasing the number of introduction locations for a given volume of first fluid to be introduced, moreover minimising pressure drop downstream

of the introduction location and minimising backmixing of second fluid.

The extent of successive momentum exchange of entities of the second fluid stream with first fluid from any one location is further increased with the width, in second fluid downstream direction, of introduced portions of first fluid at a plane of introduction locations, up to an optimum at which first fluid stream width may undesirably reduce extent of successive momentum exchange of first fluid entities, lead to pressure drop downstream of the introduction point or to poor radial dispersion. Suitably the width, in second fluid downstream direction, of introduced portions of first fluid at any one introduction location is 4 to 20 percent of the second fluid stream diameter.

The process of the invention is substantially independent of absolute momentum or densities of first and second fluids. Indeed the process may be operated with any desired density ratio of first to second fluids, of more or of less than 1, with the proviso that the momentum ratio satisfies the hereinbefore defined requirements.

A suitable ratio of momentum of first fluid perpendicular to momentum in stream axial direction of second fluid is dependent on the momentum density ratio. In general a momentum density ratio for first to second fluids of similar phase or with second fluid of higher density phase than first fluid is less than 1 and with first fluid of higher density phase than second fluid is greater than 1 but is suitably in the range 0.1 to 20,000. For dense phase mixing of atomised liquid first fluid into fluidised solid second fluid with a density ratio of first to second fluid of 0.1-1:1 for example, a suitable ratio of momentum of first fluid perpendicular to the momentum in stream axial direction of second

fluid, and second fluid is from 5:1 to 100:1 or more, preferably from 30:1 to 70:1, for example about 50:1. For lean phase mixing of fluidised solids first fluid into gaseous second fluid with a density ratio of first to second fluid of 100-2,000:1 for example, preferably of 300-1,000:1, for example 700-800:1, a suitable ratio of momentum of first fluid perpendicular to the momentum in stream axial direction of second fluid, and second fluid is from 0.15-20,000:1, preferably from 10-1,000:1, for example about 150:1.

The first fluid momentum component perpendicular to the momentum in stream axial direction of second fluid is suitably, for each circumferential introduction point, substantially radial with respect to the second fluid stream, and optionally for a portion of first fluid is also in stream tangential direction with respect to the second fluid stream. By this means first fluid is optionally circumferentially introduced in divergent manner along and about radii of the second fluid stream. This may be achieved for example by use of fluid dispersion means associated with introduction locations, whereby the multiplicity of introduction locations required to achieve substantially circumferential introduction is advantageously reduced.

Part or all of the first fluid may optionally have a momentum component co-parallel with, in addition to perpendicular to the momentum in stream axial direction of second fluid, for example in a ratio of co-parallel and perpendicular momentum components of less than 8:1, preferably of less than 2:1, more preferably of less than 1:1, most preferably of less than 1:2, for example of 1:4 or 1:8 to substantially 0:1. It is found that operation in substantial absence of a co-parallel first fluid momentum component, or with a low ratio of co-parallel and perpendicular first fluid momentum components as

hereinbefore defined is characterised by a lesser tendency to induce backmixing of second fluid, thereby reducing the duty of successive momentum exchange of respective fluid components.

The separation of any two adjacent planes of introduction is dependent on nature of fluids and on operating conditions but is suitably less than or equal to the sum of the diameter of the flow path of first fluid from any one location projected to the axis of the second fluid stream and of 0.5 times the diameter of the second fluid stream, for example is equal to the sum of the diameter of the flow path of first fluid and of 0.3 times the diameter of the second fluid stream. By this means it has been found that backmixing pockets of second fluid which are prone to formation as a result of momentum exchange are substantially interrupted and dissipated. For practical purposes the difference in diameter of the flow path of first fluid at the introduction location and projected to the axis of the second fluid stream will be greater with use of dispersive first fluid inlet means and of higher ratios of momentum of first fluid perpendicular to momentum in stream axial direction of second fluid.

As hereinbefore described, the multiplicity of introduction locations and planes of introduction is in part dependent on the extent of divergence of first fluid flow path. In general it has been found that 2 to 20, preferably 2 to 10 introduction planes may be employed, comprising 4 to 20, preferably 4 to 10 introduction locations in each plane. For example for use on a small scale, 2 to 6, preferably 2 to 4 planes containing 4 to 6 introduction locations may be employed, and for use on a large scale 4 to 10, preferably 6 to 10 planes containing 4 to 8 preferably 6 to 8 introduction locations may be employed.

Optionally a further portion of first fluid is transported within and isolated from the second fluid stream whereby it may be introduced from locations contained within the second fluid stream in a manner cooperative with circumferential introduction of first fluid. This is of particular advantage for operation of the process with second fluid streams of considerable diameter, thereby optimising radial distribution and rapidity of momentum exchange without the need to operate at undesirably high first fluid momentum or low second fluid stream momentum. Suitably the further portion of first fluid is introduced substantially concentrically within the second fluid stream with respect to circumferential introduction, preferably by means of a plurality of introduction locations comprised in one or more concentric rings. In this case the second fluid stream may be in annular flow about annular supply of first fluid to the concentric ring(s) of introduction locations or may contain and be isolated from a plurality of streams of first fluid each supplying one of a plurality of introduction locations arranged in one or more concentric rings.

In a particular advantage of the process of the present invention respective portions of first fluid are introduced from circumferential and concentric introduction locations with momentum components selected for mutual coincidence, and for maximum penetration of first fluid equal to 0.5 times the separation of such locations whereby radial distribution is optimised. Preferably separation of planes containing both circumferential and concentric introduction locations for first fluid is as above defined for the process employing substantially circumferential introduction only of first fluid, wherein the penetration length of the first fluid is taken to be approximately 0.5 times the breadth of an annular second

fluid stream i.e. of the separation between any two concentric rings of introduction locations or between the concentric ring of introduction locations and the circumferential introduction locations.

Dependent on the manner of introduction of fluid from a plurality of locations within the second fluid stream, the ratio of circumferential to in-stream introduction locations in any one introduction plane may vary. Suitably the ratio of circumferential to in-stream introduction locations is 6-2:1, preferably 3:1 or 2:1.

First fluid may be supplied to discrete introduction locations in known manner, i.e. individually via respective supply means or in common from a first fluid reservoir containing the respective introduction locations. Suitably first fluid supply is in common to discrete in-stream concentric introduction locations from an axial first fluid reservoir contained within the second fluid stream, and/or to discrete circumferential introduction locations from an annular first fluid reservoir about the second fluid stream. Preferably a plurality of discrete introduction locations are supplied in common from an annular and/or axial reservoir. It is of particular advantage for the supply of first fluid comprising more than one component that an annular or axial reservoir comprises a plurality of co-annular or co-axial first fluid reservoirs wherein each introduction location communicates with each reservoir for supply of each first fluid component.

In a further embodiment the present invention relates to an apparatus for mixing of a first fluid into a stream of second fluid as hereinbefore defined according to the process as hereinbefore defined, comprising a substantially vertical elongate conduit having in one end thereof means for introducing second fluid and having means located in the conduit wall for introducing first

fluid characterised in that the means for introducing first fluid comprises substantially circumferential inlet means arranged about a length of the conduit wall which inlets are associated with means for regulating the momentum of first fluid to be introduced.

Suitably means for regulating the momentum of first fluid to be introduced comprises impulsion means adapted to impel first fluid with a maximum projection length substantially equal to one half of the diameter of the elongate conduit, in combination with directing means adapted to provide respective portions of first fluid introduced from respective inlet openings with mutually coincident flow path thereby providing for optimum radial mixing of fluids, preventing impulsion of first fluid to the conduit wall and avoiding erosion of conduit wall or inlet openings by coincidence of first fluid thereon. It is particularly advantageous that the apparatus of the present invention is adapted to provide enhanced contact of first and second fluids allowing rapid momentum exchange and mixing.

Suitably the apparatus comprises a plurality of substantially circumferential inlets arranged about a length of conduit wall, suitably about a length of conduit wall of sufficient extent to achieve successive momentum exchange of second fluid, preferably about a length at least equal to the sum of n times the width, in conduit axial direction, of a substantially circumferential inlet and of (n-1) times the radius of the conduit wherein n = the number of substantially circumferential inlets.

A substantially circumferential inlet suitably comprises a plurality of discrete inlet openings which are located substantially in an imaginary plane perpendicular to the conduit axis in the conduit wall in such a manner as to provide substantially circumferential

introduction of first fluid. Preferably inlet openings in any one plane perpendicular to the conduit axis are symmetrically located in the circumference of the conduit. Preferably each plane perpendicular to the conduit axis contains the same number of inlet openings. Preferably inlet openings in any one plane perpendicular to the conduit axis are arranged in non-linear alignment in the conduit axial direction with respect to inlet openings in an adjacent plane perpendicular to the conduit axis. Most preferably each inlet opening in any one plane perpendicular to the conduit axis is turned by 360/2n degrees in the azimuthal direction with respect to the most proximal opening in the adjacent plane, where n is the number of symmetrically located inlet openings in any one plane.

Suitably width of inlet openings in conduit axial direction is determined in relation to the diameter of the conduit, and is preferably from 4 to 20 percent of the conduit diameter. The width may be selected for optimum rapidity of momentum exchange of fluids whereby it is preferred to employ a greater number of planes of inlet openings of moderate diameter than a lesser number of inlet openings of greater diameter whereby a more uniformly substantially cylindrical inlet means is provided.

Impulsion and directing means for first fluid suitably comprise known means for this purpose. Suitable impulsion means comprise for example fluid pumps and impulsion gases, and means for creating pressure drop at the inlet openings by operating with a high second fluid velocity or by acceleration of first fluid by profiling of inlet openings or of inlet means. Suitable directing means comprise for example a direction inducing conduit portion of the inlet opening having its axis in a plane substantially including the elongate conduit axis, and

arranged at an angle thereto of 10 to 90 degrees, for example of 40, 45, 55, 60 or 70 to 90 degrees, preferably of 70 to 90 degrees, most preferably of substantially 90 degrees. Suitably a direction inducing conduit portion comprises or extends within an opening in the wall of conduit (1), and may be cylindrical or conical of any suitable cross section such as circular or flat, with ratio of length to average diameter greater than 1.5, for example between 2 and 3 and has its axis perpendicular to and in a plane including the elongate conduit axis. Optionally such a conduit portion is one of a plurality of conduit portions aligned in parallel or to diverge in downstream direction. Optionally such a conduit means includes dispersive means such as a constriction or deflection means at the downstream opening. Suitably use of conduit portions having axes arranged at an angle to the elongate conduit axis, and including dispersive means, reduces the multiplicity of inlet openings and imaginary planes thereof required to form a substantially circumferential inlet and to achieve rapid fluids momentum exchange.

Means for introducing second fluid are suitably adapted for regulating momentum of second fluid to achieve a desired fluid stream flow rate, and preferably include means for creating pressure difference across the elongate conduit and profiling of elongate conduit for second fluid stream acceleration.

Suitable separation of any two adjacent planes of inlet openings is less than the sum of the greatest separation of the axes of the conduit portions projected to the elongate conduit axis and of 0.5 times the diameter of the elongate conduit axis, for example is equal to the sum of the greatest separation of the axes of the conduit portions projected to the elongate conduit axis and 0.3 times the diameter of the elongate conduit

axis. For practical purposes the greatest separation of the axes of the conduit portions projected to the elongate conduit axis is suitably determined as slightly greater than the greatest separation of the conduit portions in any one inlet means.

It has previously been stated that the apparatus of the invention is essentially scale independent. It has been found that by selection of an appropriate multiplicity of inlet openings in any one plane and an appropriate number of planes of inlet openings the apparatus is suited for mixing of fluids in any volume in a conduit of any diameter. The apparatus of the present invention provides excellent mixing and transport of fluids in a conduit of any conceivable diameter but suitably of 0.05 m or less to more than 3.0m. Typical conduit diameters required in the presently envisaged applications lie in the range of 0.5 to 2.5m, typically about 1.0 to 2.0m.

Suitably 2 to 20, preferably 2 to 10 planes perpendicular to the conduit axis comprise 4 to 20 preferably 4 to 10 inlet openings. In general apparatus comprising a conduit of relatively small diameter may include 2 to 4 planes containing 4 to 6 inlet openings, and apparatus comprising a conduit of relatively large diameter may include 4 to 10, preferably 6 to 10 planes containing 4 to 20 preferably 6 or 8 inlet openings.

The apparatus of the invention may additionally comprise means for introduction of first fluid from within the elongate conduit, i.e. in-stream, arranged in cooperative manner with substantially circumferential inlet means. This is of particular advantage for apparatus comprising elongate conduits of considerable diameter or for use in mixing of large amounts of or viscous fluids, whereby radial distribution and control of first fluid momentum may be more easily optimised.

Suitably in-stream inlet means are substantially concentric with respect to the circumferential inlet means, preferably comprising a plurality of inlet openings arranged in one or more concentric rings. Suitably in-stream inlet means are located on one or more elongate cylindrical or annular fluid conveying manifold(s), which manifold(s) are coaxial with or have axis in parallel to the elongate conduit axis, are closed at the downstream end and communicate at the upstream end with a fluid supply means for first fluid, and may be of uniform cross section or may comprise fluid flow accelerating profile.

Suitably the apparatus of the present invention comprising in-stream means for introduction of first fluid comprises as means for controlling the momentum of first fluid, impulsion means adapted to impel first fluid with a maximum projection length equal to one half of the separation of any two concentric rings of inlet openings or of the concentric ring of inlet openings and the elongate conduit wall, in combination with directing means associated with individual inlet openings providing mutually coincident first fluid flow path thereby providing for optimum radial mixing of fluids, and preventing erosion by impulsion of first fluid to the concentric manifold or the conduit wall. Preferably separation of any two planes containing both circumferential and concentric means is as above defined for the apparatus comprising substantially circumferential inlet means only, wherein the penetration length of the first fluid is taken to be 0.5 times the separation of any two concentric rings of inlet openings or of the concentric ring of inlet openings and the elongate conduit wall.

Dependent on the arrangement of in-stream inlet openings the ratio of circumferential to in-stream inlet

openings in any one plane may vary. Suitably the ratio of circumferential to in-stream inlet openings is 6-2:1, preferably 3:1 or 2:1.

Inlets for first fluid introduction may be any known inlet as above defined and may be of any desired cross sectional form, suitably of form adapted for control of momentum of first fluid to be introduced. Preferably inlets are adapted to achieve a premix of two fluid components of a first fluid, more preferably to achieve atomisation and/or dispersion of a first fluid or a component thereof by action of the inlet configuration for example by use of inlets of tapered profile or having constricted opening and/or by injection of an atomising gas for example by introduction of atomising gas under elevated pressure from an at least partially surrounding gas manifold via a plurality of openings in the wall of a first fluid supply means to an inlet opening.

First fluid inlets may be supplied in known manner, i.e. may be associated with individual supply lines or with a common manifold supply of first fluid. Suitably in-stream inlets are associated in common with an axial manifold, and/or circumferential inlets are associated in common with a (substantially) annular manifold. It is of particular advantage for supply of first fluid comprising more than one component that an annular or axial manifold comprises a plurality of co-annular or co-axial chambers wherein each inlet opening is associated with supply means which projects through one or more co-annular chambers and has openings in the wall thereof for entry of each first fluid component from a surrounding manifold chamber in premixing or atomising manner.

The apparatus according to the present invention may comprise any substantially vertical riser conduit. The conduit may be a premixing conduit or one of a plurality of parallel aligned premixing conduits located at the

upstream end of and integral with or within and with axis parallel to that of a further conduit for transfer or reaction of the mixed fluids stream. The apparatus may comprise a conduit having staging, static or mixer packing or other fixed internals, for example it may be an elongate fixed bed reactor in which two fluid streams are introduced and mixed.

The process and apparatus of the present invention may be used in any desired reactive multi phase process for example in FCC, gas treating such as sulphur oxide(s) removal, gas conversion such as propane dehydrogenation, other reaction such as desulphurisation or methane steam reforming, or extraction.

The process of the present invention may be operated with use of advanced process control and on-line optimisation systems. Accordingly momentum controlling means of the apparatus of the present invention suitably comprises advanced process control and on-line optimisation systems. By monitoring of fluid densities and velocities, momentum ratio may be controlled for optimised first fluid penetration and radial mixing.

The apparatus for use in the process of the present invention is now illustrated in non-limiting manner with reference to Figures 1 to 5 and in which reference numerals relating to corresponding parts are the same.

Figure 1 is an elevation view of an apparatus according to the present invention comprising 24 inlet openings for first fluid. The apparatus of Figure 1 comprises a conduit (1) having inlet openings for first fluid in the wall thereof, shown in region A, and having in the base thereof inlet (2) for second fluid and ring or disc manifold (3) for introduction of aerating or lift gas via apertures (4). The introduction region A comprises inlet openings (5) arranged equidistant in imaginary planes (a-f). Openings (5) in adjacent planes

are turned with respect to each other by 45 degrees in the azimuthal direction. A peripheral manifold (6) supplied by supply lines (7) communicates with inlet openings (5) for supply of first fluid. Momentum control means (not shown) operate by regulation of flow rate of first and second fluids, at inlet openings (5) and at upstream end of fluid introduction region A, and are denoted by pressure difference dP1 and dP2 respectively. Suitable momentum control means for first fluid comprise means for adjustment of its flow and/or for adjustment of the flow rate of a component thereof, such as for example of an atomising fluid, thereby resulting in dP1 adjustment. Similarly, suitable momentum control means for second fluid comprise means for adjustment of its flow and/or for adjustment of the flow rate of a component thereof, such as for example of an aerating or liftgas via (3) and (4), thereby resulting in dP2 adjustment. In an alternative arrangement, manifold (3) may be dispensed with and a further series of inlet openings (5) may be arranged in region B for introduction of aerating or lift gas via the process of the invention, separately from introduction of first fluid introduced via region A.

Figure 2 is a detail vertical cross section through the wall of the liftpot (1) of Figure 1 illustrating two preferred design options for inlet openings (5) communicating with manifold (6), particularly suited to introduction of atomised liquid or fluidised solid as first fluid. Manifold (6) is suitably arranged as an annular chamber about conduit (1). Inlet openings (5) comprise one or more conduit portions comprising or extending within the conduit wall, having axis in or substantially parallel to a plane containing the conduit axis and at an angle of substantially 90 degrees thereto.

Illustrated in option 1, for introduction for example

of atomised liquid first fluid, each inlet opening in a given imaginary plane is associated with one end of one or more supply lines (51) (two shown) projecting through manifold (6). The walls of supply lines (51) contain apertures (52) in the region contained within manifold (6).

In option 1a, liquid first fluid component is supplied via supply lines (72) to supply lines (51). Atomising fluid supplied under pressure via supply line (71) to manifold (6) contacts liquid in supply lines (51) via apertures (52) causing atomisation thereof, prior to introduction of the resulting first fluid into conduit (1).

In option 1b, supply lines (51) are supplied with liquid first fluid component either by means of apertures (52) or by means of an open end to the supply line terminating within the manifold, from an outer annulus of manifold (6) comprising two co-annular chambers (62, 63) divided by a partition illustrated as broken line (6'), whereby as few as one supply line (72) may be sufficient to supply liquid to the outer co-annular manifold chamber. It is advantageous to employ supply lines (51) projecting through both manifolds whereby liquid supplied to the outer manifold enters supply lines (51) via openings in the walls thereof, for easy access for maintenance purposes.

Illustrated in option 2, for introduction for example of fluidised solid first fluid, each inlet opening (5) in a given imaginary plane comprises one or more openings in the common manifold/liftpot wall. Supply line (71) may comprise a ring or disc manifold or an annular chamber integral with the lower wall of manifold (6). Line (73) provides an outlet for excess fluidising fluid. Respective components of first fluid, comprising fluidising gas and solids, are supplied to supply lines

(71, 72). Fluidising fluid supplied under pressure via line (71) contacts a bed of solid in manifold (6) causing fluidisation thereof, enabling flow of the resulting first fluid into conduit (1).

Figure 2a, insert cross section through X-X in conduit (1) wall, illustrates an arrangement of an inlet opening comprising 5 supply lines (51, option 1) or openings (option 2).

Figure 3 is a vertical cross section of an apparatus according to Figure 1 comprising peripheral manifold (6) supplied by lines (7) with one or more components of first fluid. The apparatus additionally comprises axial manifold (61) for concentric introduction of first fluid, associated with line (74) for supply of first fluid. Inlet openings (5) may be located in any one of regions A, B and C, and may be as shown in Figure 2 above for example with use of first fluid comprising more than one component, or may be simple openings in the manifold (6, 61) wall communicating with the liftpot for example with use of first fluid comprising a single fluid component. In the latter instance, manifold (61) comprises an inverse arrangement of that illustrated in Figure 2, as shown in the cross-sectional insert in introduction region B, wherein manifold (61) is suitably comprised of two co-annular chambers, an axial chamber (62) for one component and an annular chamber (63) for a second component, each having a supply line (74) and in which inlet opening supply lines (51) project through annular chamber (62) and are supplied via an open end from axial chamber (63). Inlet openings may be located in any one of regions A, B and C. Momentum control means (not shown) regulate flow rate of first and second fluids as hereinbefore described, at inlet openings (5) and at upstream end of fluid introduction region A, B or C respectively, denoted by pressure difference dP1 and dP2

respectively (illustrated for region B as upstream introduction region).

Figure 4 is an elevation view of an apparatus according to the present invention comprised as one of a plurality of apparatus (1) located within and with axis parallel to a further conduit (11). In this case manifold (62) supplied by line (72) is suited for supply of fluidised solid first fluid to inlet openings (5) and is formed between an optional or partial top closure (8) i.e. is (partially) open topped or contained, and between the walls of conduits (1) and (11) and a disc manifold (31), or closed base located below a ring manifold (31). Line (71) supplies a ring or disc manifold (31) having openings (41) for introduction of fluidising fluid into a bed of fluidised solid first fluid. Conduits (1) project through manifold (62) and disc manifold or closed base (31), whereby they are supplied with second fluid by line (2) communicating with the base portion of conduit (11) and supply mixed first and second fluids to the top portion of conduit (11). Line (73) provides an outlet for excess fluidising fluid, in the instance that manifold (62) is contained by means of a top closure (8).

Figure 5 is a vertical cross section of an apparatus (1) according to the present invention of diameter D, illustrating an inlet opening (5a) in a first plane (a) of openings and location of an adjacent plane (b) of inlet openings (5b). The inlet comprises a plurality of conduit portions (15) of which two peripheral and a central portion are shown. The separation of peripheral portions (15) is given by distance (di) and of the first fluid projected to the axis (z) by distance (dz) whereby planes (a, b) are separated by a distance less than (dz + 0.5D), as shown equal to (di + 0.5D).

The following examples serve as non-limiting illustration of the invention.

EXAMPLE 1

The process of the invention was carried out in an apparatus resembling an FCC riser comprising a liftpot (1) of 21 cm in diameter, corresponding to Figure 1. Inlets (5) comprised four equidistant side-wall openings located in each of two horizontal planes, the openings in a first plane turned by 45 degrees in the azimuthal direction with respect to those in the second plane. Inlets comprised a plurality of direction inducing conduit portions having axis contained in and parallel to a plane including the liftpot axis and at an angle thereto of substantially 90 degrees. A stream of fluidised catalyst particles was introduced continuously via inlet (2) and caused to flow upwardly by means of fluidising gas introduced via apertures (4) in manifold (3) and a pressure difference created along the length of the liftpot upstream of inlets (5). A liquid first fluid (comprising liquid nitrogen) was introduced in atomised form with zero vertical momentum component via two rings of four inlets (5). Radial penetration length of first fluid as a function of the liftpot (1) diameter was calculated as 0.7 at the base of the riser and 0.5 at the riser top. Operating conditions are given in Table 1 below. The mixed fluid stream was monitored to obtain radial velocity profiles for given distances along the fluid stream flow path. The profiles are given in Figures 6a and 6b.

COMPARATIVE EXAMPLE 1

A process not according to the invention was carried out as described in Example 1, except that liftpot (1) comprised only one plane of inlet openings (5). The apparatus thus resembled an apparatus according to the prior art, in which neither substantially circumferential introduction of first fluid nor successive momentum exchange were provided for. Operating conditions are

given in Table 1 below. The velocity profile at 42 cm above the inlets (5) was substantially the same as that at the inlet elevation, showing that momentum exchange had not taken place. The mixed fluid stream was monitored to obtain radial velocity profiles for given distances along the fluid stream flow path. The profiles are given in Figures 7a and 7b.

COMPARATIVE EXAMPLE 2

A process not according to the invention was carried out as described in Example 1, except that liftpot (1) was of 10 cm diameter, and inlet openings (5) were taped shut whereby the apparatus was operated without introduction of first fluid into the second fluid stream. Operating conditions are given in Table 1 below. The particles velocity and concentration profiles at 10 cm and 80 cm above the taped inlets location were measured. The profiles are given in Figures 8a and 8b. Significant segregation of particles from fluidising gas and significant non-uniformity in velocity and concentration were observed. This illustrates that fluidised catalyst flow in a conventional riser/liftpot would result in breakdown of plug flow prior to entry to the riser base. The mixed fluid stream was monitored to obtain radial velocity and concentration (volume fraction) profiles at given distances along the fluid stream flow path.

EXAMPLE 2

The process of Example 1 above was repeated with use of a liftpot (1) of 10 cm diameter. Operating conditions are shown in Table 1. The mixed fluid stream was monitored to obtain radial velocity and concentration (volume fraction) profiles at given distances along the fluid stream flow path. The profiles are given in Figure 9a and 9b. Uniform profiles of concentration and velocity of particles were observed.

TABLE I - prevailing operating conditions

Ex. No.	Riser/-lift-pot dia-meter (cm)	G(lift) (kg/s)	G(F2)	G(F1) (kg/s)	Flux (F2) ($kg/m^2.s$)
Ex. 1	21	0.12	0.9 t/d	0.28	425
Comp. 1	21	0.12	0.9 t/d	0.28	425
Ex. 2	10	0.038	0.19 kg/s	0.083	395
Comp. 2	10	0.038	0.11 kg/s	0.0	229

G denotes flow rate of given fluid;
Flux is to be understood to mean flow rate density;
F2 and F1 denote second and first fluids resp.

Results of the Examples 1 and 2 given in Figures 6 to 9 attached when compared with the Comparative Examples above, illustrate that the invention provides excellent mixing of feed and catalyst stream resulting in plug flow for the length of the liftpot, typically up to distances equal to more than eight times the liftpot diameter and thus for a considerable distance along the riser length, in contrast to the inferior mixing and stream stability displayed by the comparative examples.

Results of Examples 1 and 2 above, moreover illustrate that the process of the invention is substantially scale independent.

Variations in fluid flow conditions may result in further refinements such as upheld plug flow for a greater distance up the liftpot, and in improved radial mixing of fluids.

CLAIMS

1. Process for mixing a first fluid into a substantially vertically upward stream of second fluid having momentum substantially in stream axial direction, wherein both first and second fluids comprise a reactive component which components when brought into contact undergo rapid reaction within a contact time of less than 10 seconds, and wherein first fluid is heterogeneous and comprises the reactive component as the more dense of the heterogeneous components and a substantially inert component as the less dense of the heterogeneous components, which process comprises introduction into the second fluid stream of first fluid having a momentum component perpendicular to the momentum in stream axial direction of second fluid, characterised in that the first fluid is introduced substantially circumferentially about a length of the second fluid stream such that the second fluid stream is subjected to successive momentum exchange with the circumferential length introduced first fluid rendering a substantially vertically upward mixed fluids stream in which first fluid is radially distributed, with momentum substantially in stream axial direction.

2. Process according to claim 1 wherein first fluid is heterogeneous comprising fluidised solid particles or atomised liquid as the more dense reactive component and gaseous fluid as the less dense substantially inert component.

3. Process according to either of claims 1 and 2 wherein second fluid comprises fluidised solid particles or gaseous fluid as the reactive component.

4. Process according to any of claims 1 to 3 wherein first and second "reactive" fluid components react to form a lower density inert low friction product or component.

5. Process according to any of claims 1 to 4 wherein the substantially inert, lower density component of first fluid is introduced in a first upstream circumferential introduction length or at the upstream portion of the circumferential introduction length and the first fluid is introduced as hereinbefore defined at a second downstream circumferential introduction length, or at the downstream portion of the circumferential introduction length.

6. Process according to any of claims 1 to 5 wherein a transfer gas is present in an amount of 0.1-50 wt%, preferably 1-15 wt% in viscous liquid, such as hydrocarbonaceous feed as first fluid, or in an amount of 0.01-5 wt%, preferably 0.05-1 wt% in fluidised solids as first or second fluid.

7. Process according to any of claims 1 to 6 wherein first fluid is introduced via discrete introduction locations contained in a plurality of planes perpendicular to and along a length of the second fluid stream.

8. Process according to any of claims 1 to 7 wherein circumferential introduction is about a length of the second fluid stream at least equal to the sum of n times the width, in second fluid downstream direction, of a circumferential introduction location and of (n-1) times the radius of the second fluid stream, wherein n = the number of circumferential introduction locations.

9. Process according to any of claims 1 to 8 wherein substantially circumferential introduction of first fluid about the second fluid stream is achieved discretely via introduction locations contained in a plurality of planes along the length of the second fluid stream and

distributed about the circumference thereof, preferably introduction locations in a first plane are non aligned with respect to those in an adjacent plane, for example have a triangular pitch which may be equilateral or otherwise.

10. Process according to any of claims 1 to 9 wherein the ratio of momentum of first fluid perpendicular to the momentum in stream axial direction of second fluid, and second fluid is from 5:1 to 100:1 or more, preferably from 30:1 to 70:1, for example about 50:1, for dense phase mixing of for example atomised liquid first fluid into fluidised solid second fluid of density ratio 0.1-1:1, and is from 0.15-20,000:1, preferably from 10-1,000:1, for example about 150:1 for lean phase mixing of for example fluidised solids first fluid into gaseous second fluid, of density ratio 700-800:1.

11. Process according to any of claims 1 to 10 wherein the first fluid momentum component perpendicular to the momentum in stream axial direction of second fluid is substantially radial with respect to the second fluid stream, and optionally for a portion of first fluid is also in stream tangential direction with respect to the second fluid stream.

12. Process according to any of claims 1 to 11 wherein first fluid has substantially no further momentum component co-parallel with momentum in stream axial direction of the second fluid stream, or has a ratio of momentum components co-parallel therewith and perpendicular thereto of less than 8:1, preferably of less than 1:2.

13. Process according to any of claims 1 to 12 wherein a further portion of first fluid is transported within and isolated from the second fluid stream whereby it is introduced from locations contained within the second fluid stream in a manner cooperative with circumferential

introduction of first fluid, preferably substantially concentrically within the second fluid stream with respect to circumferential introduction of first fluid.

14. Process according to any of claims 1 to 13 wherein first fluid comprises more than one component, wherein a plurality of discrete introduction locations are supplied in common via reservoir(s) annular and/or axial with respect to the second fluid stream axis, comprising a plurality of co-annular and/or co-axial first fluid reservoirs wherein each introduction location communicates with each reservoir for supply of each first fluid component.

15. Process as hereinbefore defined with reference to any of examples 1 or 2, or figures 6 to 9.

16. Apparatus for mixing of a first fluid into a stream of second fluid as hereinbefore defined, according to the process of any of claims 1 to 15, comprising a substantially vertical elongate conduit having in one end thereof means for introducing second fluid and having means, located in the conduit wall, for introducing first fluid characterised in that the means for introducing first fluid comprises substantially circumferential inlet means arranged about a length of the conduit wall which inlets are associated with means for regulating the momentum of first fluid to be introduced.

17. Apparatus according to claim 16 for use in a fluid catalytic cracking reactor, in a gas treating reactor such as a sulphur oxide(s) removal reactor, in a gas conversion reactor such as a propane dehydrogenating reactor, in other reactor such as desulphurisation or methane steam reforming reactor or in an extracting unit.

18. Apparatus as hereinbefore defined with reference to any of figures 1 to 5.

FIG.1

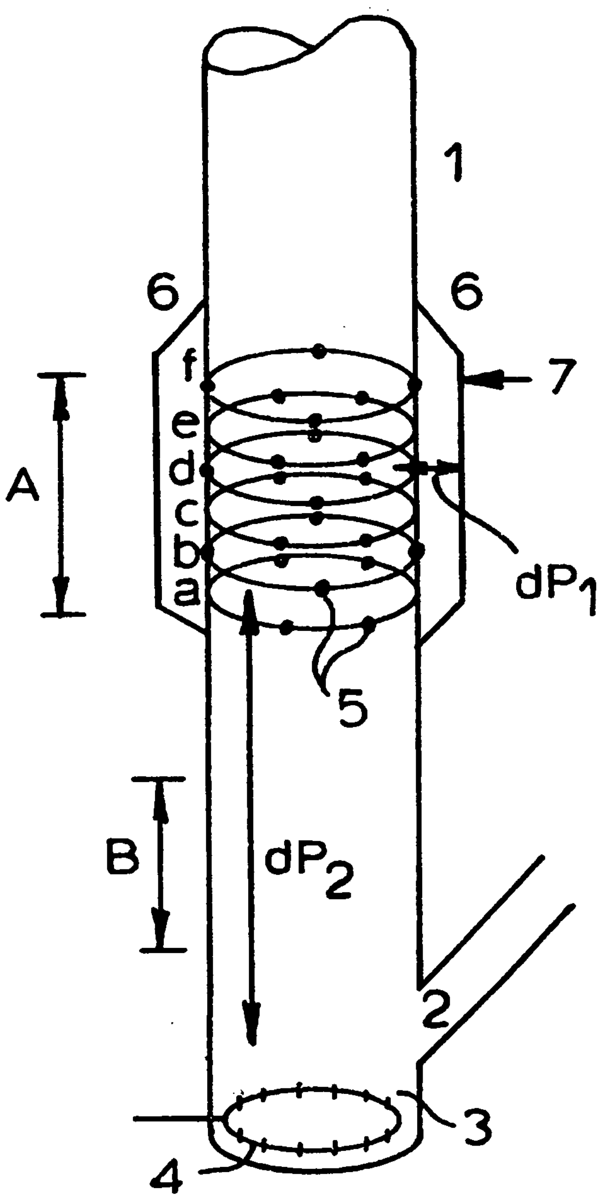


FIG. 2

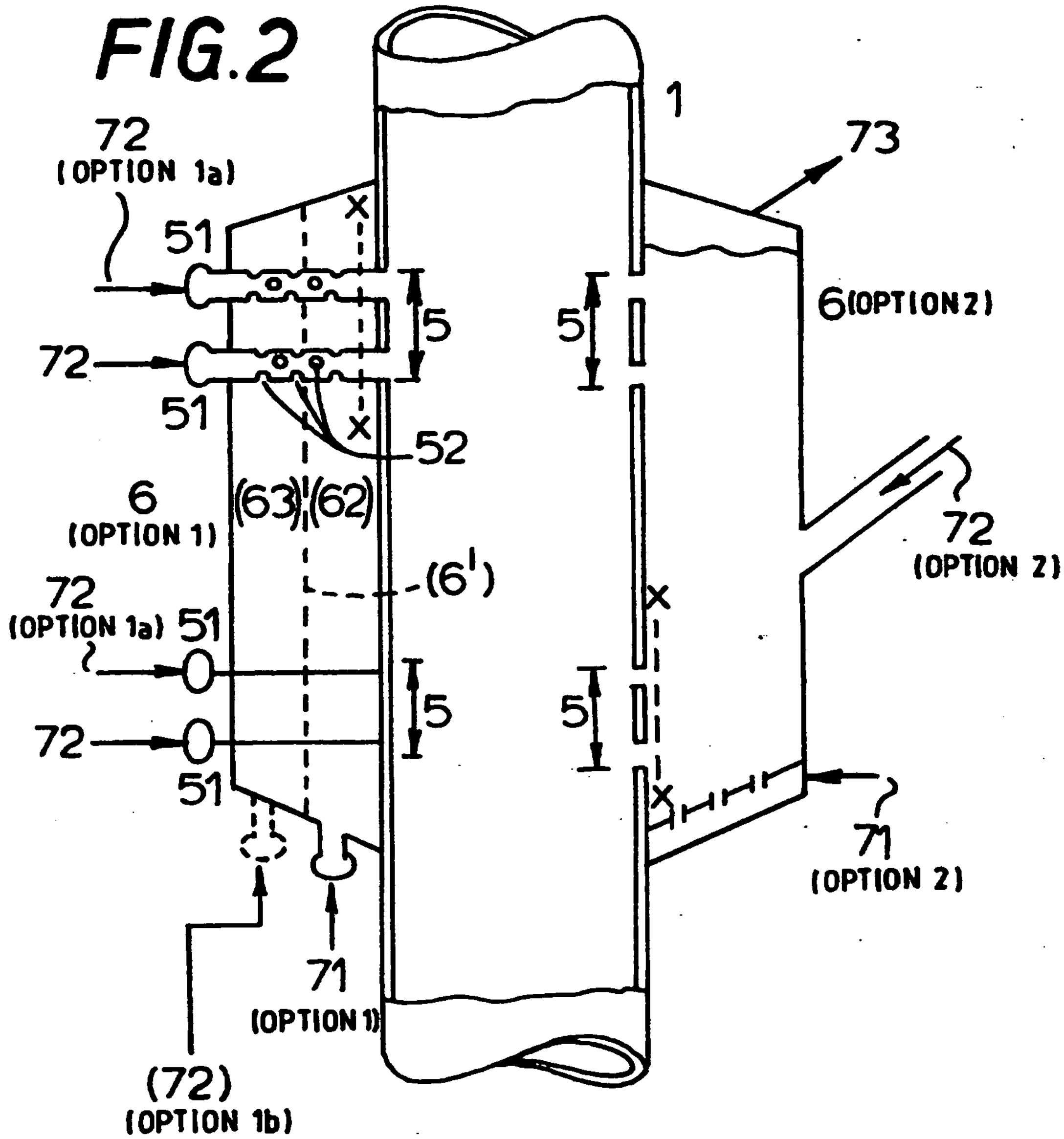


FIG. 2a

Insert: cross section through x-x

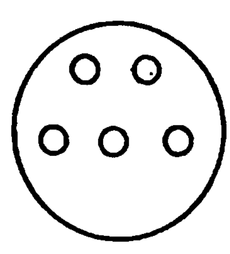


FIG.3

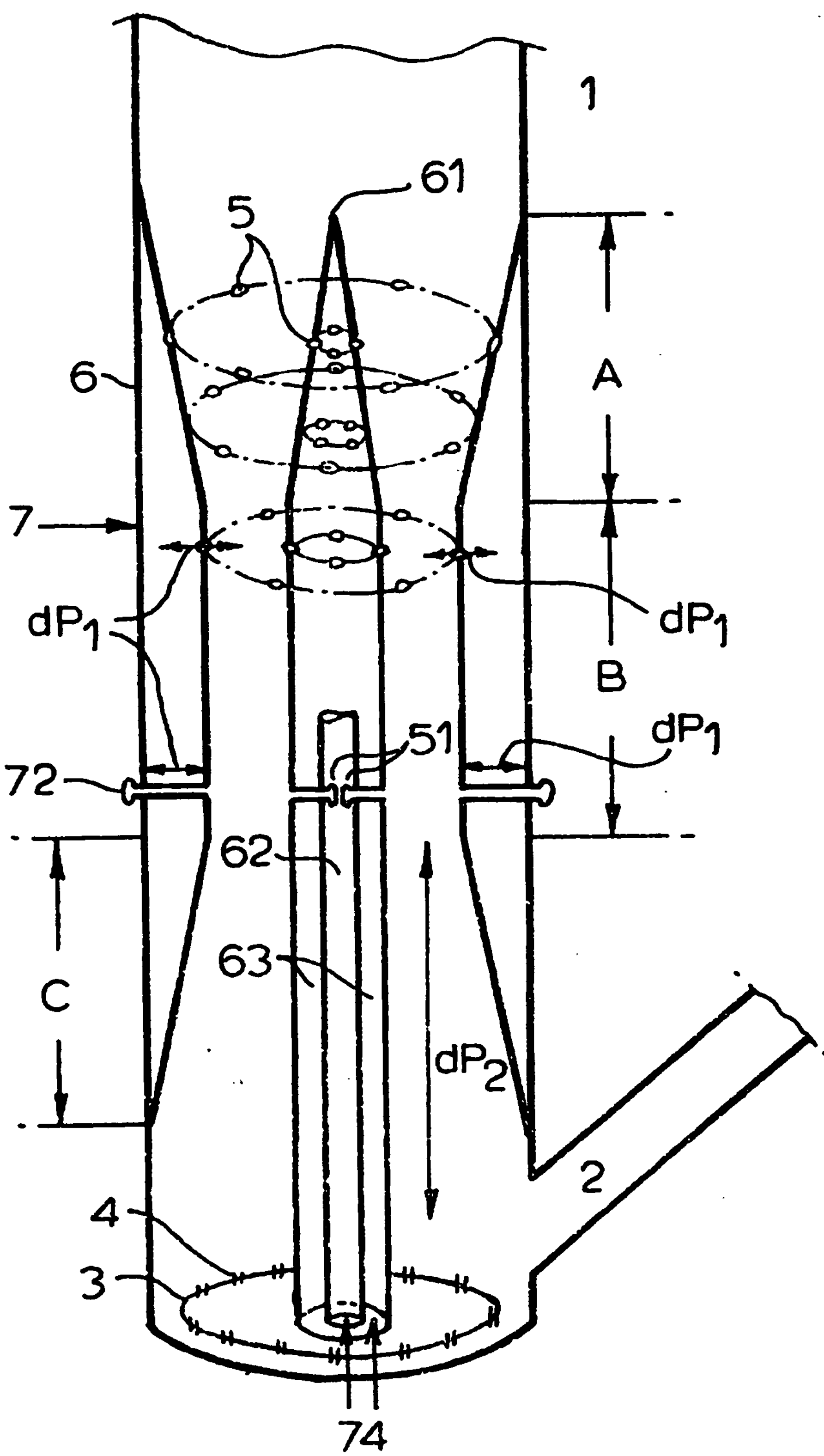


FIG. 4

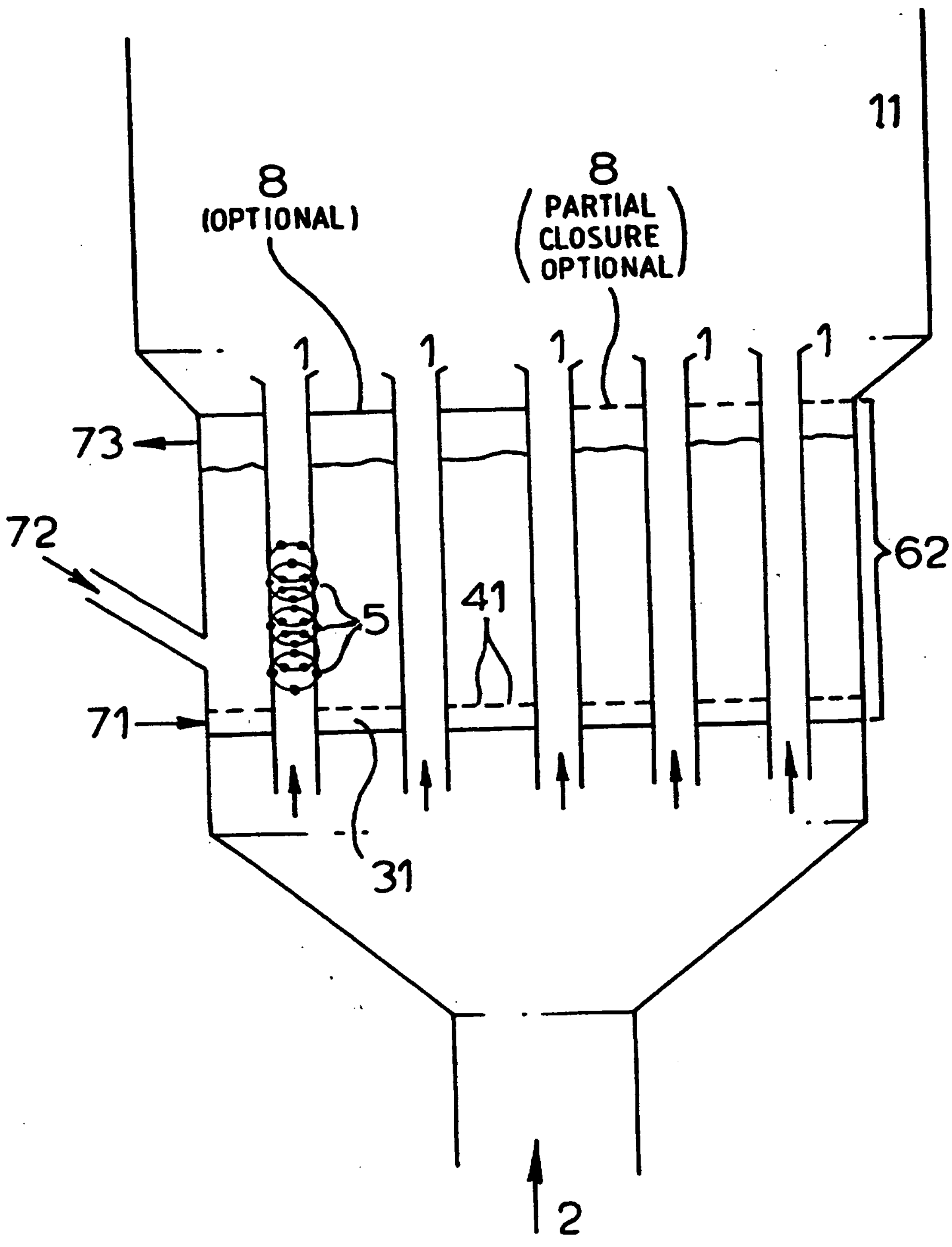

11
8
(OPTIONAL)
8
PARTIAL
CLOSURE
OPTIONAL
1
1
1
1
1
73
72
5
41
62
71
31
2

FIG.5

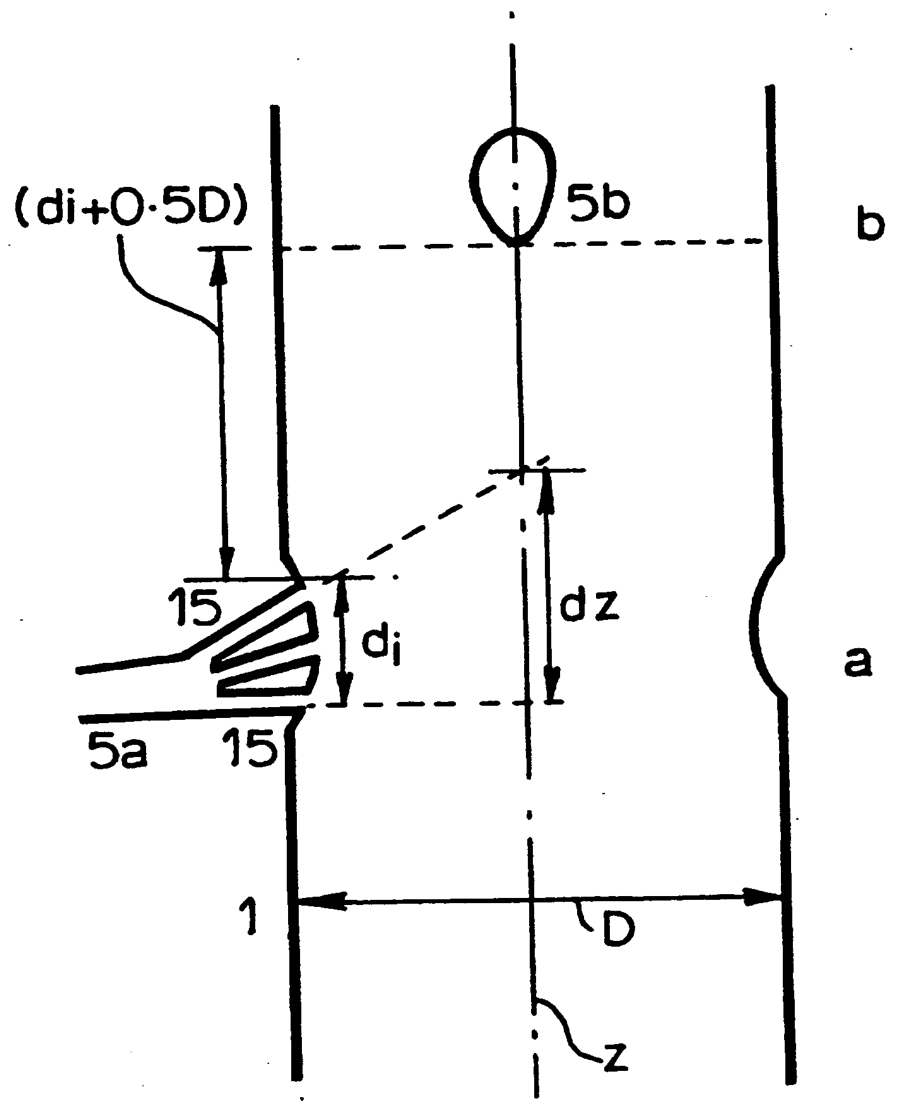


FIG. 6a

Particles velocity profile 21 cm above upstream introduction location plane (Liftpot dia. 21cm; 2 planes of first fluid inlet openings)

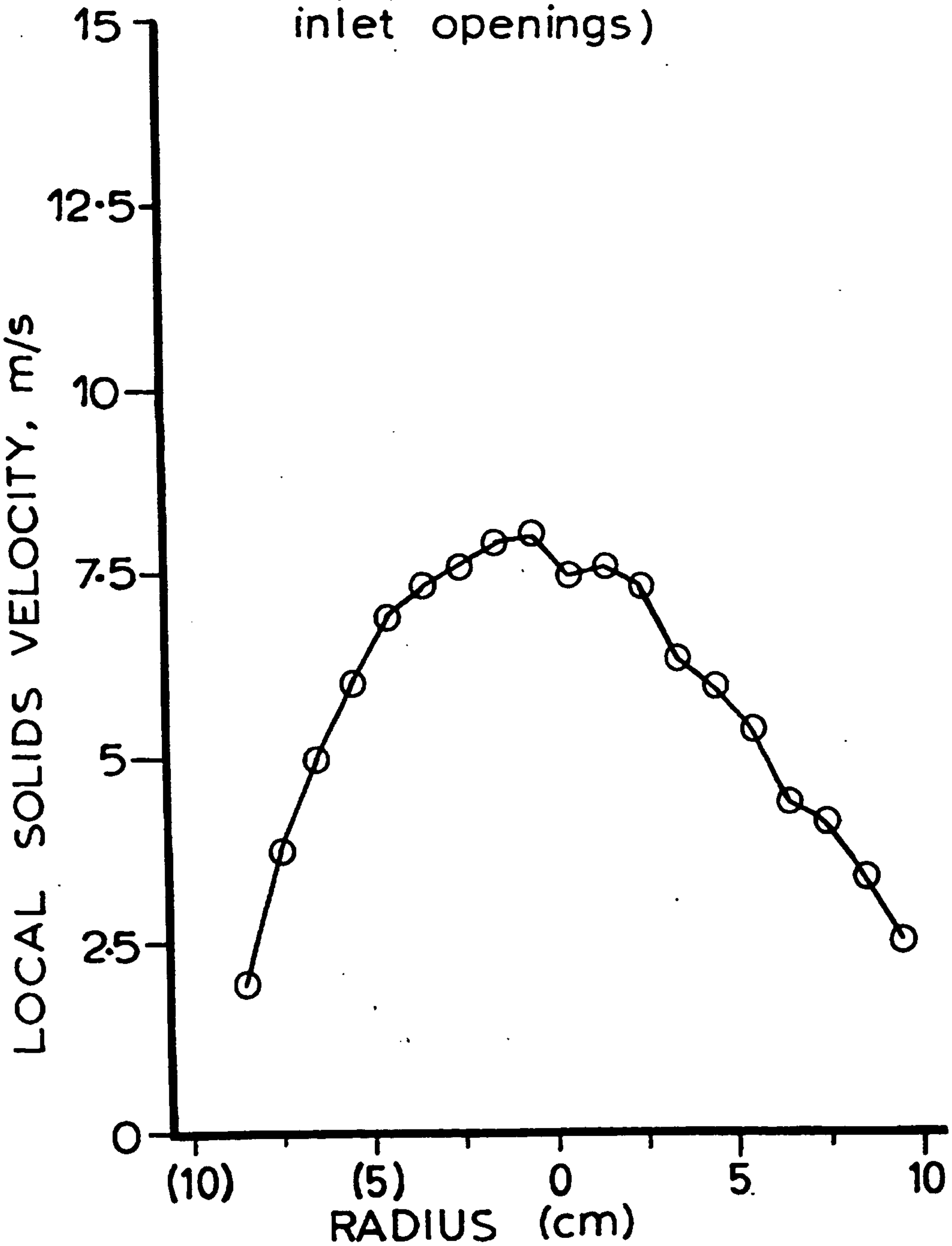


FIG.6b

Particles velocity profile 42cm above upstream introduction location plane (liftpot diameter 21cm; 2 planes of first fluid inlet openings)

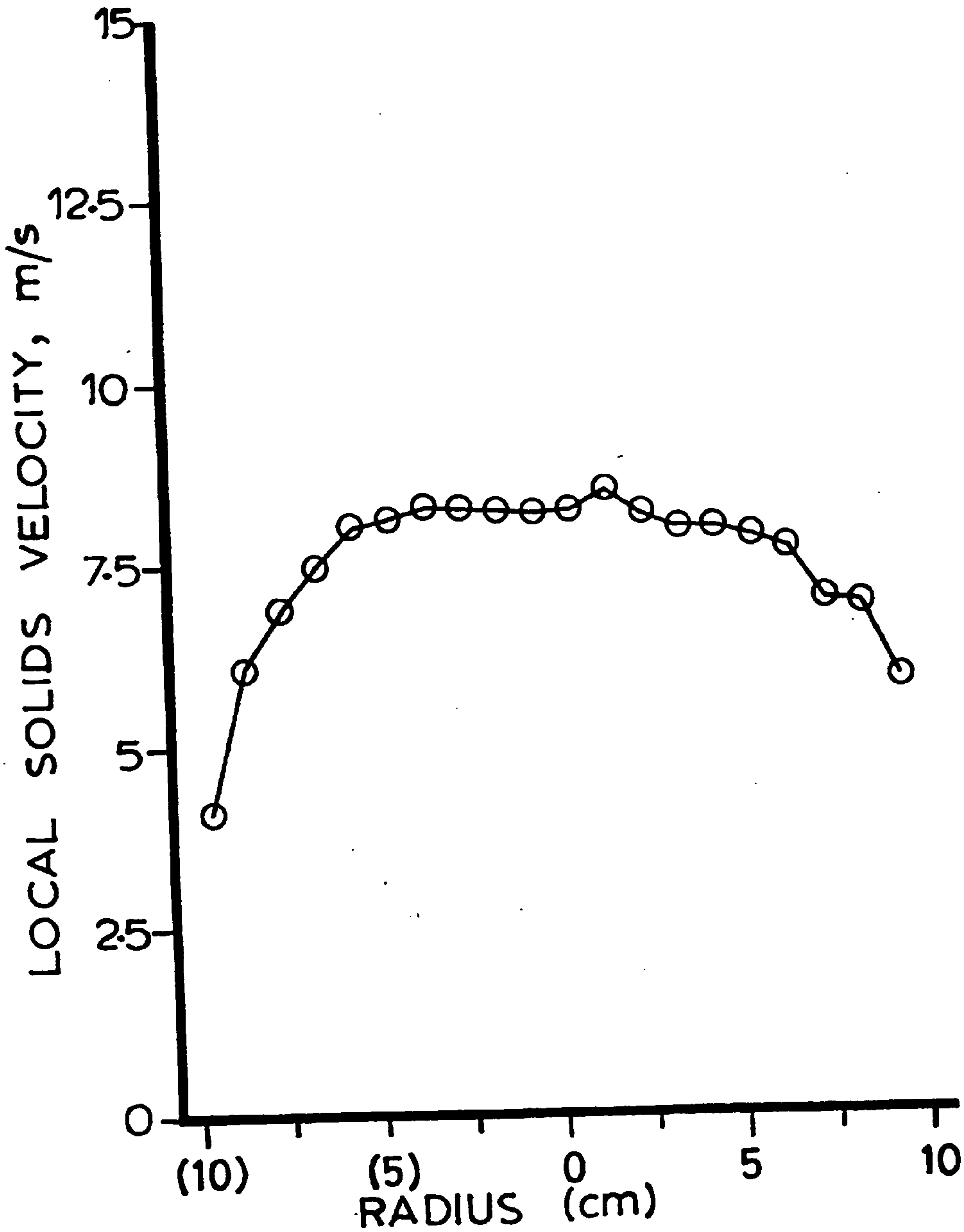


FIG.7a

PARTICLES VELOCITY PROFILE
0 cm above upstream introduction location plane
(Liftpot 21cm dia.;1 plane of first fluid inlet openings)

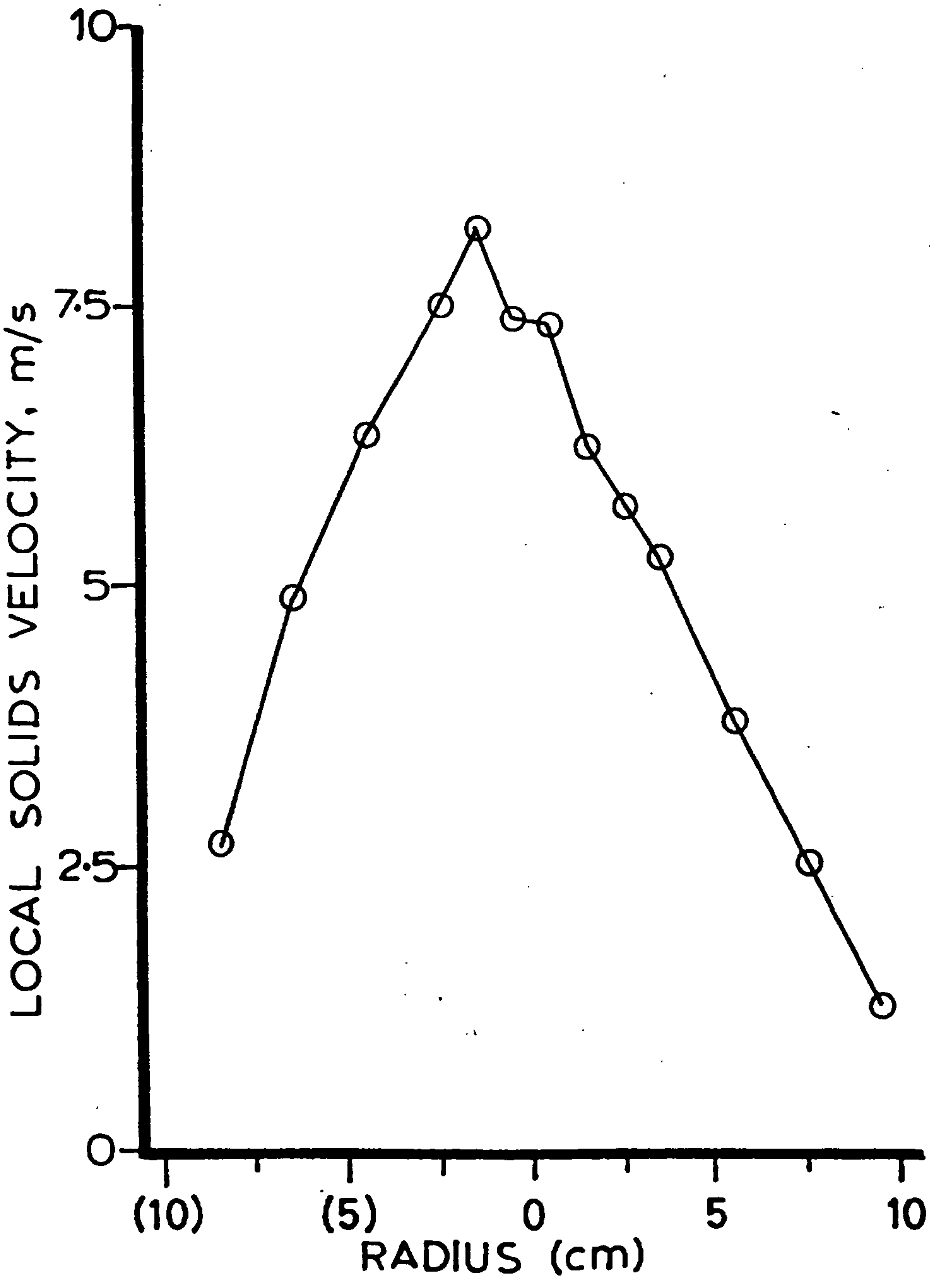


FIG.7b

Particles velocity profile
42 cm above upstream introduction location plane (Liftpot 21 cm diameter; 1 plane of first fluid inlet openings)

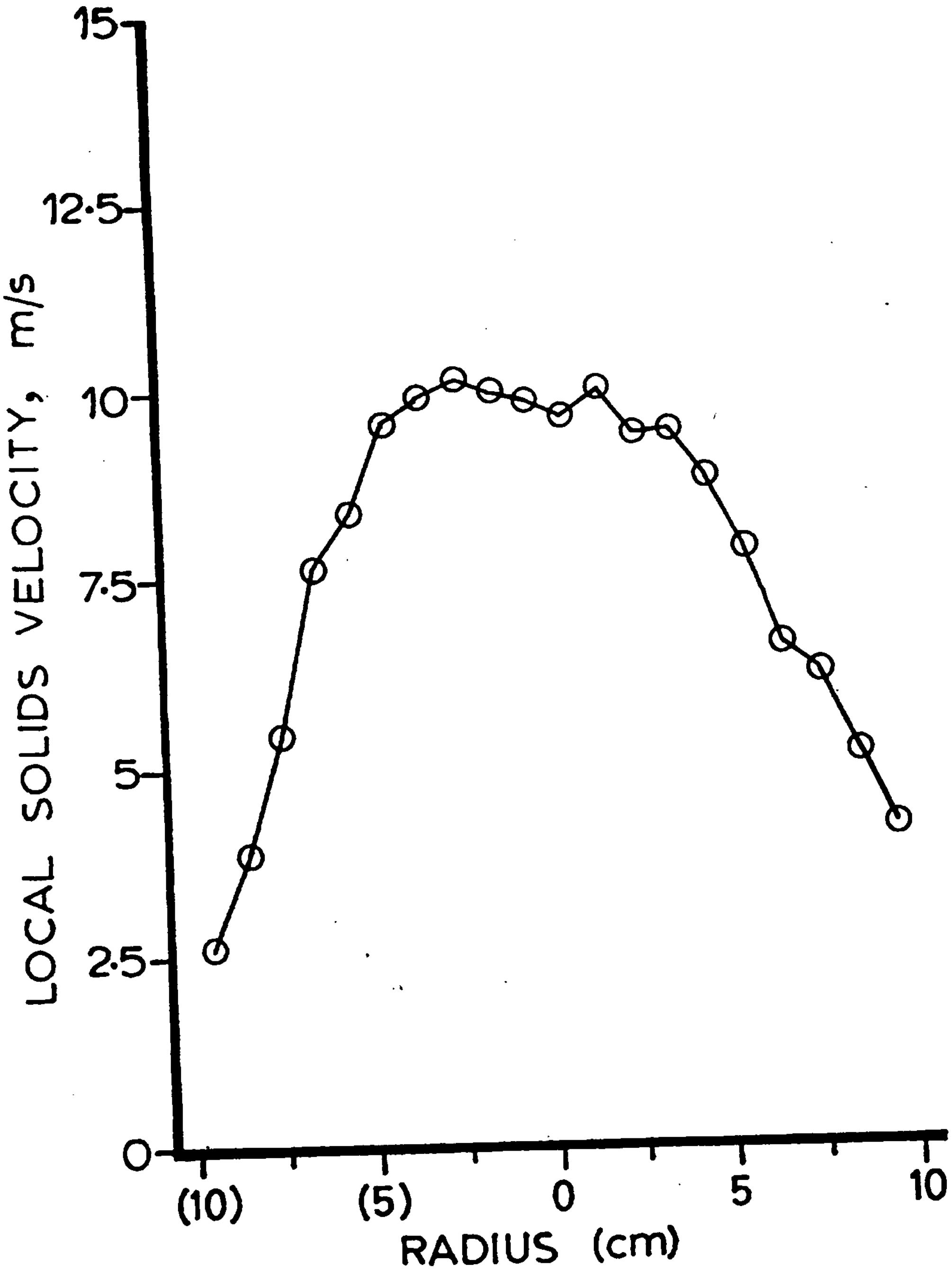


FIG.8a

Particles velocity and concentration profiles 10cm above upstream introduction location plane (Liftpot 10 cm dia.; O planes of first fluid inlet openings)

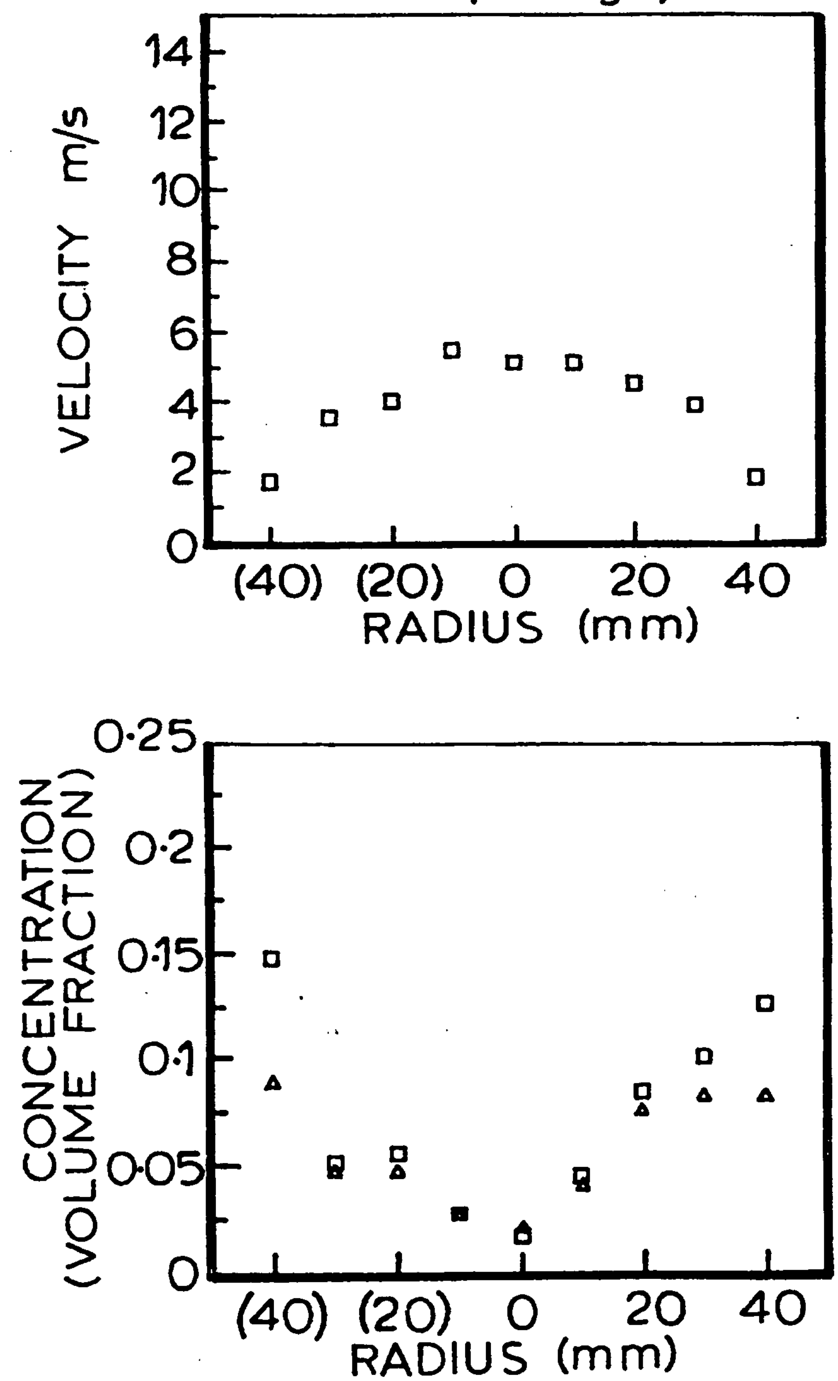


FIG.8b

Particles velocity and concentration profiles 80cm above upstream introduction location plane (Liftpot 10cm diameter; 0 planes of first fluid inlet openings)

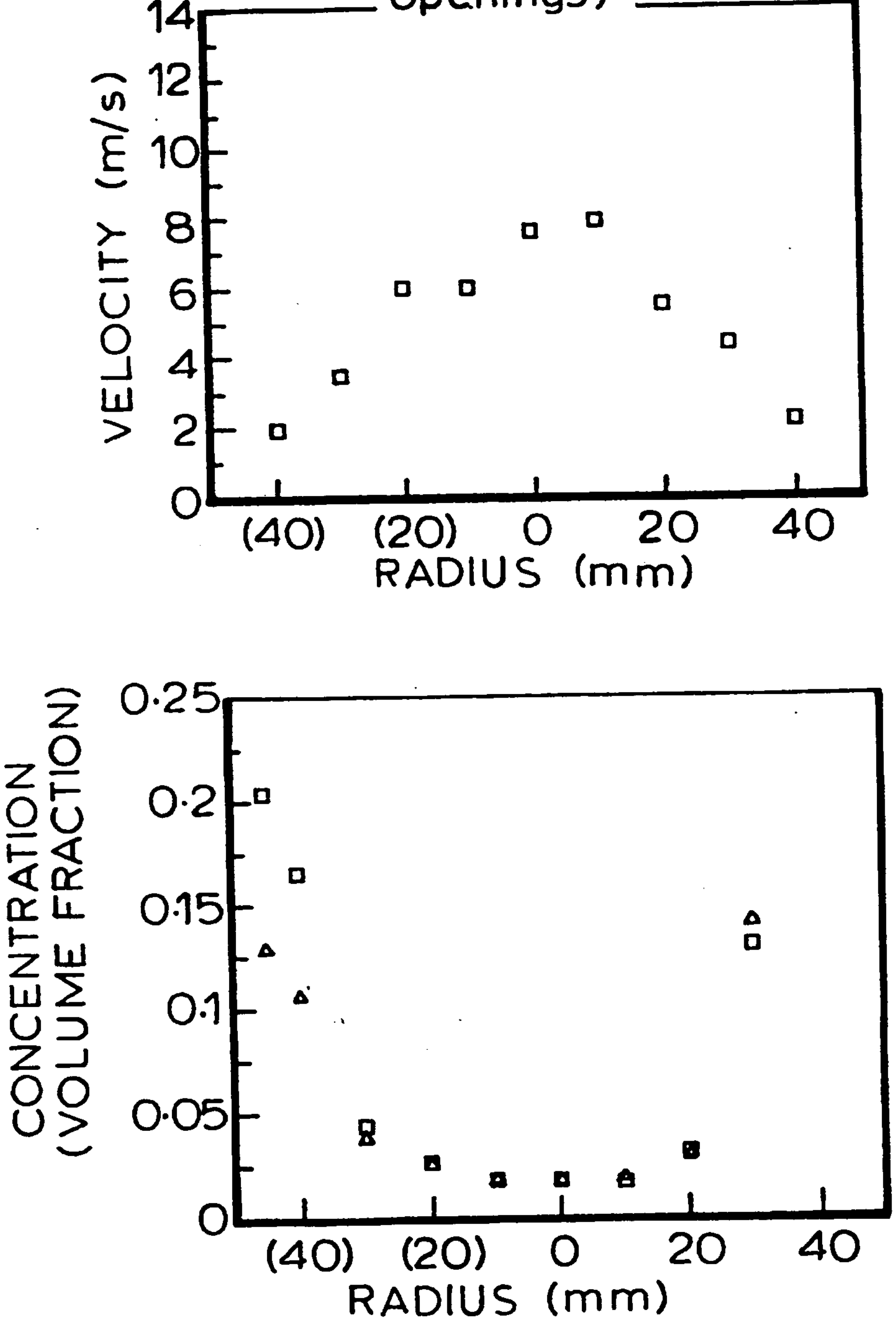


FIG.9a

Particles velocity profile 10cm above upstream introduction location plane (Liftpot 10cm diameter; 2 planes of first fluid inlet openings)

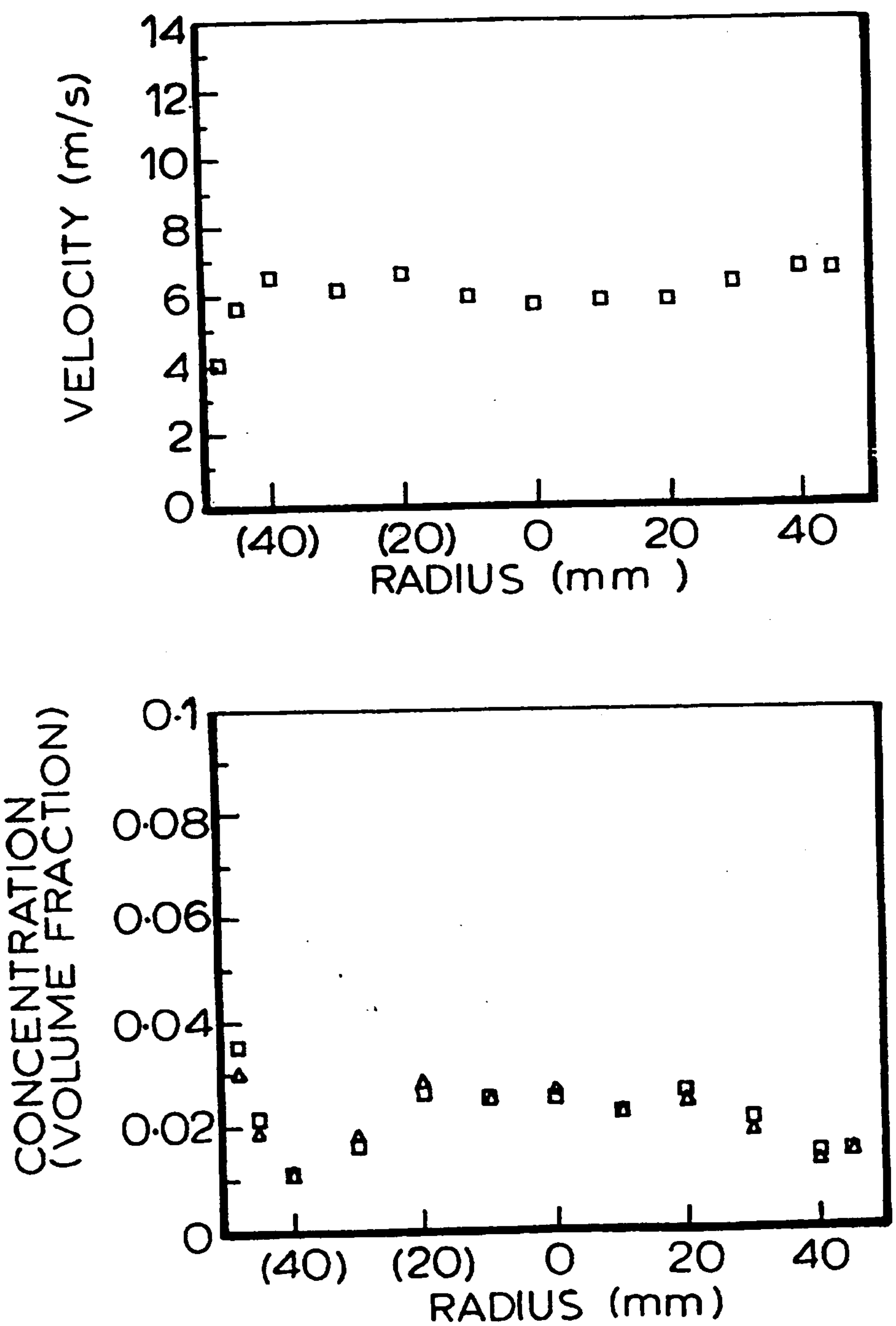
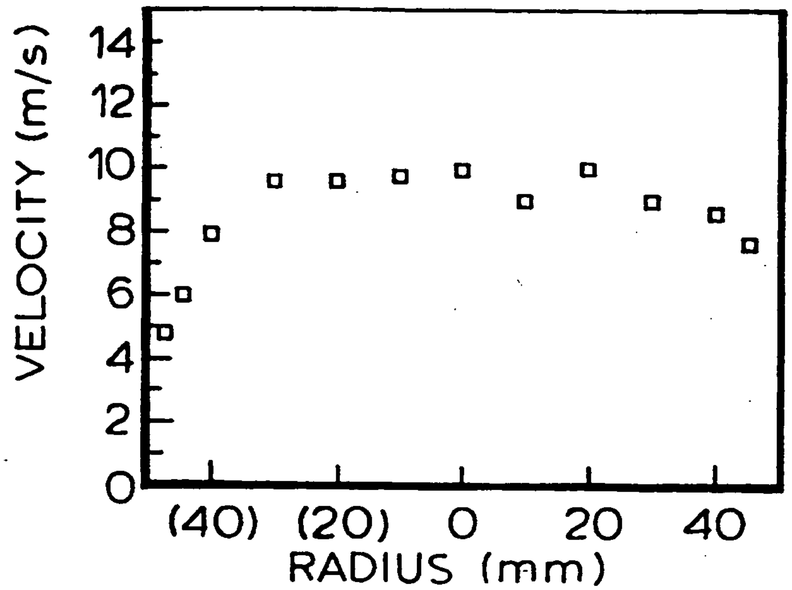
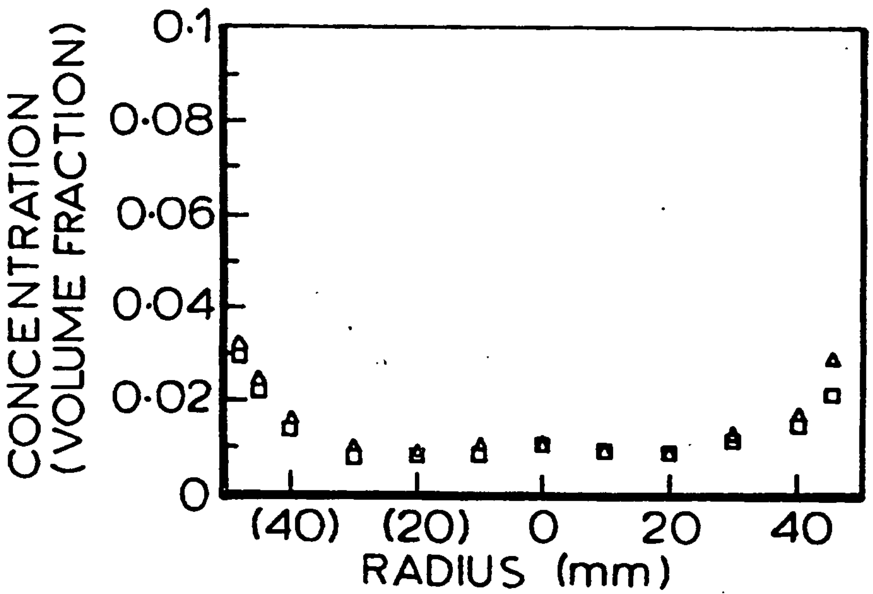


FIG. 9b

Particles velocity profile 80cm above upstream introduction location plane (Liftpot 10cm diameter; 2 planes of first fluid inlet openings)





INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/EP 95/03324

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B01F5/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

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X	EP,A,0 533 104 (STEINECKER) 24 March 1993 see the whole document ---	1-3, 7-12,15, 16,18
X	US,A,4 110 973 (HAEFLICH) 5 September 1978 see the whole document --- -/--	1-3, 7-12,15, 16,18

[X] Further documents are listed in the continuation of box C.

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1

Date of the actual completion of the international search	Date of mailing of the international search report
18 December 1995	11.01.96

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INTERNATIONAL SEARCH REPORT

Inter   nal Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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		BR-A-	9205779	02-08-94
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PCT/EP 95/03324

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